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CLASSIFICATION AND MENSURATION SUBSYSTEM
(CAMS) REWORK EXPERIMENT (Lockheed
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TECHNICAL MEMORANDUM

LACIE PHASE I CLASSIFICATION AND MENSURATION
SUBSYSTEM (CAMS) REWORK EXPERIMENT

By

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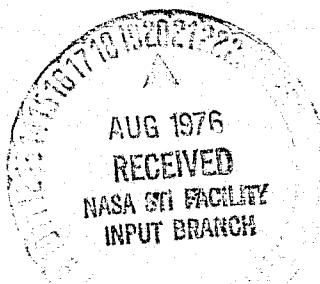
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1. INTRODUCTION

An experiment was designed to test the ability of the Classification and Mensuration Subsystem (CAMS) rework operations to improve wheat proportion estimates for segments that had been processed previously. Eleven segments were selected for the experiment, including three in Kansas and three in Texas, with the remaining five segments distributed in Montana and North and South Dakota. The Kansas and Texas sites were selected to provide information on the southern Great Plains. The remaining sites were selected to augment the knowledge acquired from the blind site study of the mixed and spring wheat sites in the northern Great Plains.

The acquisition dates were selected to be representative of imagery available in actual operations. No more than one acquisition per biophase would be used, and biophases were to be determined by actual crop calendars. All sites were intensive test sites (ITS's) over which at least two passes had been made, and each had an acquisition from either biophase 2 or 3.

All sites were worked by each of four Analyst-Interpreter/Data Processing Analyst (AI/DPA) Teams randomly selected from teams which were familiar with CAMS rework methodology. Each AI/DPA Team reviewed the initial processing of each segment and accepted or reworked it for an estimate of the proportion of small grains in the segment. Specific procedures and required rework products are described in section 2. The classification results are given in table I; table II lists the acquisitions; and tables III and IV describe classification errors and performance results between CAMS regular and ITS rework.

The experimental design provided 44 classification runs with a factor of 4 (AI/DPA Teams) times 11 (sites). However, two of the

sites were declared unworkable by some of the teams and were subsequently dropped from the experiment.

2. PROCEDURES

- a. The AI/DPA Team reviews processed acquisitions for a segment and determines whether the processed acquisition acreage estimation is acceptable.
- b. The AI/DPA Team determines if rework is necessary.
- c. If rework is not necessary, the AI/DPA Team confers on the results and forwards the data to the Accuracy Assessment Team.
- d. If rework is necessary, the AI/DPA Team confers on the rework technique.
- e. The segment is reworked by an AI/DPA Team, using the following rework products:
 - All classification maps
 - All evaluation forms
 - All ancillary data
 - Color film for all classified acquisitions
 - Batch printouts

The results are discussed and forwarded to the Accuracy Assessment Team.

- f. As a ground rule, selected acquisitions are not discussed between the teams.
- g. Team arrangement:
 - One AI/DPA interpretation is selected randomly from AI/DPA Teams A, B, C, or D.
 - Four AI/DPA Teams are selected randomly from all experienced AI/DPA Teams.

3. DATA ANALYSIS

Since each AI/DPA Team was provided with CAMS classification results from regular processing of each segment, the CAMS rework proportion estimates are expected to be correlated with the initial estimates.

To study classification errors of the CAMS rework procedure and to determine whether or not proportion estimates are improved, a linear regression was performed using the CAMS rework estimate as the dependent variable and the CAMS regular estimate as an independent variable. The $\text{arc sin } \sqrt{p}$ transformation, where p denotes proportion, was employed to stabilize the variance and thus enable valid statistical inferences to be made. Details on terminology and results are presented in section 3.2. The regression is significant, and 44 percent of the total errors in the CAMS rework estimates are caused by errors in the CAMS regular estimates.

Elimination of the effect of CAMS regular outputs on the CAMS rework results was considered, and residuals were obtained. An analysis of variance (ANOVA) was performed on the residuals in order to study whether or not the CAMS rework performance varied according to AI/DPA Team and/or site. These results are given in section 3.3. No significant difference is detected between the four AI/DPA Teams. However, a difference is observed between sites but is significant only at the 10-percent level. Since this ANOVA is for a 4-by-9 factorial design with no replications, the interaction between sites and teams cannot be evaluated and hence cannot be tested for its statistical significance.

3.1 ANALYSIS OF ERROR SOURCES

An analysis of error sources by segment is set out below.

- Segment 1687, Hand County (1), South Dakota – Only biophases 1 and 3 were available for rework. Biophase 3 was acquired in late July, which, according to the crop calendar, was the time for harvest and should probably be called biophase 4. Some grass in this biophase has the signature of ripening wheat. Therefore, labeling errors occurred, which resulted in overestimation.
- Segment 1960, Finney County, Kansas – Some of the field numbers used in the fall-planted wheat inventory report could not be located on the updated field overlay. This indicates that some wheatfield boundaries were changed later in the growing season. Thus, the original small-grain proportions, which were computed on the basis of the fall inventory report, were inadequate. As a result, the ground-truth small-grain proportions presented in table I may be in error. The results for this segment can be interpreted only with reservations.

Some of the wheatfields in this segment were in very poor condition and did not have a wheat signature. For this reason, they were not recognized by the interpreters as wheat and were classified as nonwheat. A threshold of 8.6 percent occurred in the ground-truth area. According to the ground-truth report, a major portion of the thresholded area is actually wheat, which indicates a wheat signature was missed.

- Segment 1962, Saline County, Kansas – The ground-truth small-grain proportions were computed based on the fall-planted wheat inventory report. No final inventory was available for this segment.

AI/DPA Teams C and D missed some wheat signatures, which caused the underestimation. Both AI/DPA Teams A and B had estimates which were slightly higher than the ground truth; a very thorough

comparison of the classification map with the ground truth indicates that both are good classifications.

- Segment 1963, Rice County, Kansas - This segment contains narrow strip fields, which are less than one pixel in width and for which no training fields were provided. Most of the pixels in these fields were classified as mixed. It was also found that most of these mixed pixels were actually wheat but misclassified as nonwheat, resulting in a reduction of at least 6 percent in wheat from the estimated small-grain proportions.

In addition to the problems caused by the narrow strip fields, labeling errors were made by AI/DPA Teams C and D.

- Segment 1965, Burke County, North Dakota - Every team underestimated the small-grain proportions in this segment. Some wheat signatures were mislabeled as nonwheat. Only biophases 1 and 2 were available for rework. Use of a later biophase acquisition would make it possible to identify these signatures correctly.
- Segment 1969, Toole County, Montana - The classification results were generally good. AI/DPA Team C mislabeled one nonwheat signature, which probably caused overestimation.
- Segment 1970, Liberty County, Montana - As was the case with segment 1963, problems occurred because of narrow strip fields, resulting in the misclassification of mixed pixels.
- Segment 1978, Randall County, Texas - Small-grain proportions were originally underestimated at least 25 percent by the AI/DPA Teams. The major problem was volunteer wheat which was counted as small grain. These fields of volunteer wheat were plowed when the data were acquired. The ground-truth proportion was corrected to exclude these fields from the small grain. The ground-truth proportion is therefore reduced 13 percent.

Missing wheat signatures were also an error source. Signatures were mislabeled because of the low ground cover (60 to 79 percent).

- Segment 1979, Deaf Smith County, Texas - All the volunteer wheatfields in this segment were plowed when data were acquired. After the ground-truth proportions were adjusted to exclude the volunteer wheat, they were almost identical to the classification result.
- Segment 1980, Oldham County, Texas - All the volunteer wheat-fields were listed in the crop inventory report as summer fallow. Original ground-truth proportions were adequately computed.
- Segment 1986, Hand County (2), South Dakota - Since clouds and haze were observed in biophases 2 and 3, only biophase 1 was considered workable. Because of the poor data, this segment should not have been worked or reworked.

3.2 REGRESSION ANALYSIS

The linear regression equation is

$$y = 0.02833 + 0.9928x$$

where

y = arc sin/CAMS rework estimated proportion

- arc sin/true proportion

and

x = arc sin/CAMS initial estimated proportion

- arc sin/true proportion

The ANOVA for regression is shown in the following table.

| <u>Source</u> | <u>Degrees of freedom</u> | <u>Sum of squares</u> | <u>Mean square error</u> | <u>F-ratio</u> |
|---------------|---------------------------|-----------------------|--------------------------|----------------|
| Regression | 1 | 0.278 | 0.278 | a26.5 |
| Residual | 34 | .357 | .010 | |

^aSignificant at 1-percent level of significance.

$$\text{Thus, } R^2 = \frac{0.278}{0.635} = 0.44$$

3.3 ANALYSIS OF VARIANCE

The ANOVA in this section is performed to study the site effect and the AI/DPA effect on the classification proportion errors.

| <u>Source</u> | <u>Degrees of freedom</u> | <u>Sum of squares</u> | <u>Mean square error</u> | <u>F-ratio</u> |
|---------------|---------------------------|-----------------------|--------------------------|----------------|
| Site | 8 | 0.12972 | 0.01622 | a1.954 |
| AI/DPA | 3 | .02817 | .00939 | 1.131 |
| Residual | <u>24</u> | <u>.19908</u> | <u>.0083</u> | |
| Total | 35 | .35698 | | |

^aSignificant at 10-percent level of significance.

4. CONCLUSION

The following conclusions are made with respect to the ITS's selected for the present CAMS rework experiment.

- CAMS rework performance is significantly correlated with CAMS initial performance in this test procedure. However, only 44 percent of the error variability in CAMS rework results is caused by the CAMS initial errors. This implies that CAMS rework performance is as variable as the CAMS initial classification performance.
- No significant difference exists between performances of the two procedures, which implies that the CAMS rework procedures offer no significant improvement.
- No significant difference is apparent in terms of different AI/DPA Teams, which implies that the CAMS is repeatable for reviewing and reworking a segment.

- The effect of sites on the CAMS rework performance is statistically significant but only at the 10-percent level.

TABLE I.-- CAMS REWORKED SMALL-GRAIN PROPORTIONS, PHASE I ITS
[Δ = Average of team proportions minus ground-truth proportions]

| Segment | Biophases | AI/DPA Team | | | | Δ | Ground truth |
|--------------|-----------------------------------|-------------|--------|--------|--------|----------|--------------|
| | | A | B | C | D | | |
| 1687 | 1,3 | 35.2 | 38.8 | 33.0 | (a) | 5.9 | 29.8 |
| 1960 | 1,3 | b 19.7 | b 19.7 | b 19.7 | b 19.7 | -11.7 | c 31.4 |
| 1962 | 1,2 | 67.3 | 70.0 | d 42.9 | d 27.7 | -9.8 | c 61.8 |
| 1963 | 1,2 | 31.7 | 29.5 | d 28.1 | d 16.2 | -15.0 | e 41.4 |
| 1965 | 1,2 | d 32.5 | d 32.5 | d 30.6 | d 32.5 | -20.3 | c 52.3 |
| 1969 | 1,2,3,4 | 48.3 | 45.4 | 60.3 | 33.1 | 5.2 | 42.8 |
| 1970 | 1,2,4 | 32.0 | 58.4 | 62.7 | 58.0 | 11.3 | e 41.5 |
| 1978 | 1,3 | d 25.6 | d 25.6 | d 25.6 | d 32.6 | -14.6 | f 41.9 |
| 1979 | 1,3 | 30.9 | 30.9 | 30.9 | 30.9 | -.2 | f 31.1 |
| 1980 | 1,3 | 56.9 | 54.3 | 58.4 | 66.5 | -1.3 | 60.3 |
| 1986 | 1, ^g 2, ^g 3 | 19.6 | 24.4 | (a) | (a) | 15.2 | 6.8 |
| Overall -3.7 | | | | | | | |

^aAI/DPA Team declared segment unsuitable for classification.

^bMissing signatures.

^cCould be in error; no complete ground truth was available for verification.

^dMislabeling.

^eContains narrow strip fields.

^fWas recomputed to exclude the volunteer wheat.

^gExtremely hazy data.

TABLE II.- ACQUISITIONS FOR CAMS REWORK EXPERIMENT

| Segment | Acquisition number for biophase | | | |
|-------------------|---------------------------------|-------|-------|-------|
| | 1 | 2 | 3 | 4 |
| 1687 | 74133 | | 75205 | |
| 1960 | 74291 | | 75150 | |
| 1962 | 74324 | 75131 | | |
| 1963 | 74289 | 75131 | | |
| 1965 | 75155 | 75191 | | |
| ^a 1967 | | | | |
| 1969 | 75161 | 75179 | 75215 | 75233 |
| 1970 | 75142 | 75179 | | 75233 |
| 1978 | 74291 | | 75133 | |
| 1979 | 74291 | | 75133 | |
| 1980 | 74291 | | 75133 | |
| ^b 1986 | | | | |

^aNot suitable for processing because of lack of ground truth.

^bNot suitable for processing because of haze and clouds.

TABLE III.-- ERROR SUMMARY FOR ITS REWORK

[$\hat{p} - p = \text{error}$, where $\hat{p} = \text{estimated percentage of wheat}$ and
 $p = \text{ground-truth percentage of wheat}$]

| Segment | AI/DPA Team | | | | |
|-------------------------|-------------|-------|-------|--------------------|----------------|
| | A | B | C | D | O ^a |
| 1960 | -11.7 | -11.7 | -11.7 | -11.7 | -11.7 |
| 1962 | 5.5 | 8.2 | -19.9 | -34.1 | -19.9 |
| 1963 | -9.7 | -11.9 | -13.3 | -25.2 | -13.3 |
| 1965 | -19.8 | -19.8 | -21.7 | -19.8 | -19.8 |
| 1969 | 5.5 | 2.6 | 17.5 | -4.7 | 5.5 |
| 1970 | -3.5 | 16.9 | 21.2 | 16.5 | -3.5 |
| 1978 | -16.3 | -16.3 | -16.3 | -9.3 | -16.3 |
| 1979 | -.2 | -.2 | -.2 | -.2 | -.2 |
| 1980 | -3.4 | -6.0 | -1.9 | 6.2 | -3.4 |
| Team average | | | | ^b -6.12 | -9.18 |
| Team standard deviation | | | | ^b 12.99 | 9.11 |

^aThis column lists the original results from Team O, which classified the segment during the Four-AI Experiment. The AI was randomly chosen from the four AI's and turned out to be AI Y. These results were from the latest results analyzed during the year by AI Y and were used as the starting point for the CAMS rework analysis.

^bFor AI/DPA Teams A through D.

TABLE IV.— COMPARISON OF CAMS REGULAR VERSUS ITS REWORK RESULTS

| | |
|---------------------------------|--|
| I = Improved result | |
| W = Worse than original | |
| N = Original accepted | |
| U = Segment declared unworkable | |

| Segment | AI/DPA Team | | | |
|---------|-------------|-------|--------|--------|
| | A | B | C | D |
| 1687 | I | W | I | U |
| 1960 | N | N | N | N |
| 1962 | I | I | N | W |
| 1963 | I | I | N | W |
| 1965 | N | N | W | N |
| 1969 | N | I | W | I |
| 1970 | N | W | W | W |
| 1978 | N | N | N | I |
| 1979 | N | N | N | N |
| 1980 | N | W | I | W |
| 1986 | I | I | U | U |
| Totals | 12 I's | 3 U's | 10 W's | 19 N's |